U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-257 681

Reductions in Water Consumption and Flow of Sewage-Report to Congress

Environmental Protection Agency

June 1974

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No. PB-257 681
4. Title and Subtitle Reductions in Water Consumption and Flow of Sewage. Report to the Congress			5. Report Date Jun 74 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Environmental Protection Agency, Washington, D. C. Office of the Administrator			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

The preliminary results of studies and investigations by the Environmental Protection Agency on devices, systems, incentives, policies, and other methods of reducing the total flow of sewage including, but not limited to, uncecessary water consumption in order to reduce the requirements for, and the costs of, sewage and wastewater treatment systems are reported to the Congress.

The major flow reduction topics discussed in the report are (1) infiltration/inflow, (2)domestic wastewater, (3) industrial wastewater, and (4) Environmental Protection Agency programs related to wastewater flow reduction. The investigations in these areas revealed potentials for reductions in water consumption and wastewater flows.

17. Key Words and Document Analysis. 17a. Descriptors

*Water consumption,
*Sewage treatment,
*Flow rate,
Cost engineering,
Requirements,
Waste water,
Fluid infiltration,
Standards,
User needs,
Expenses,
Industrial waste treatment,
Reduction,
Toilets,
Industrial water.

17b. Identifiers/Open-Ended Terms

Use rates

17c. COSATI Field/Group 13 B, 5 C

18. Availability Statement National Technical Information Service Springfield, Virginia 22161	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 36p.
	20. Security Class (This Page UNCLASSIFIED	22. Price 4.00/2.25

271064

PB 257 681

REPORT TO THE CONGRESS

REDUCTIONS IN WATER CONSUMPTION AND FLOW OF SEWAGE

JUNE 1974

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

U.S. Environmental Protection Agency

REDUCTION IN WATER CONSUMPTION

AND

FLOW OF SEWAGE

Report to the Congress

U.S. ENVIRONMENTAL PROTECTION AGENCY

June 1974

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 27 1974

OFFICE OF THE
ADMINISTRATOR

Dear Mr. President:
Dear Mr. Speaker:

We respectfully submit this report on the preliminary results of studies and investigations by the Environmental Protection Agency on reducing water consumption and the total flow of sewage, as required by Section 104(o)(2) of the Federal Water Pollution Control Act Amendments of 1972.

Future annual reports on wastewater flow reductions will be incorporated in the report required by Section 516(a) of the Act. The future reports will include recommendations for any legislation that may be required to provide for the adoption and use of devices, systems, policies, or other methods of reducing water consumption and reducing the total flow of sewage.

Sincerely yours,

Russell E. Train

Russell E. Train
Administrator

Honorable Gerald R. Ford
President of the Senate
Washington, D.C. 20510

Honorable Carl B. Albert
Speaker of the House of Representatives
Washington, D.C. 20515

ABSTRACT

The preliminary results of studies and investigations by the Environmental Protection Agency on devices, systems, incentives, policies, and other methods of reducing the total flow of sewage including, but not limited to, unnecessary water consumption in order to reduce the requirements for, and the costs of, sewage and wastewater treatment systems are reported to the Congress.

The major flow reduction topics discussed in the report are (1) infiltration/inflow, (2) domestic wastewater, (3) industrial wastewater, and (4) Environmental Protection Agency programs related to wastewater flow reduction. The investigations in these areas revealed potentials for reductions in water consumption and wastewater flows.

Under the general program categories of infiltration/inflow, user charges, wastewater discharge standards, cost-effectiveness, facility planning, and effluent guidelines, the Environmental Protection Agency will stimulate reductions of wastewater flow.

CONTENTS

	Page
Abstract	iii
Recommendation	1
Introduction	3
Wastewater Flow-Reduction Studies	7
Infiltration/Inflow	7
Domestic Wastewater	9
Industrial Wastewater	13
Wastewater Flow Reduction	17
Programs	17
Future Research Efforts	20
References	23
Appendix A – Cost-Effectiveness Examples	29
Appendix B – Pricing Policies	33

RECOMMENDATION

This report presents the preliminary results of studies and investigations by the Environmental Protection Agency on devices, systems, policies, and other methods of reducing the total flow of sewage.

The implementation of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, was an important step toward improving the quality of our Nation's water resources. Wastewater flow-reduction programs can aid in the accomplishment of this objective. Several sections of the Act should provide the basis for understanding and developing future flow-reduction programs. The Act requires an evaluation of existing sewer systems to eliminate excessive infiltration/inflow; a system of user charges; a cost-effectiveness analysis; and wastewater discharge standards.

Research and development on infiltration/inflow, domestic wastewater reduction, and industrial wastewater recycle/reuse will offer a number of potentials for reductions in water consumption and sewage flow.

Additional legislation to provide for the adoption and use of devices, systems, policies, or other methods of reducing water consumption and reducing the total flow of sewage is not recommended at this time. This recommendation will be reassessed after the effects of Public Law 92-500 in this area are evaluated.

INTRODUCTION

The purpose of this report is to present the preliminary results of studies and investigations or devices, systems, incentives, policies, and other methods of reducing the total flow of sewage, including unnecessary water use, as required under Section 104(o)(2) of the Federal Water Pollution Control Act Amendments of 1972. This report contains a general overview and state-of-the-art presentation on the reduction of wastewater flows.

As this Nation has developed, its water use has increased substantially faster than its population. Since 1900, agricultural water use has increased about 6½ times; industrial water usage, about 4½ times; and public water use, about 9 times. During this period the population increased about 2 times and water use per person increased about 3½ times.

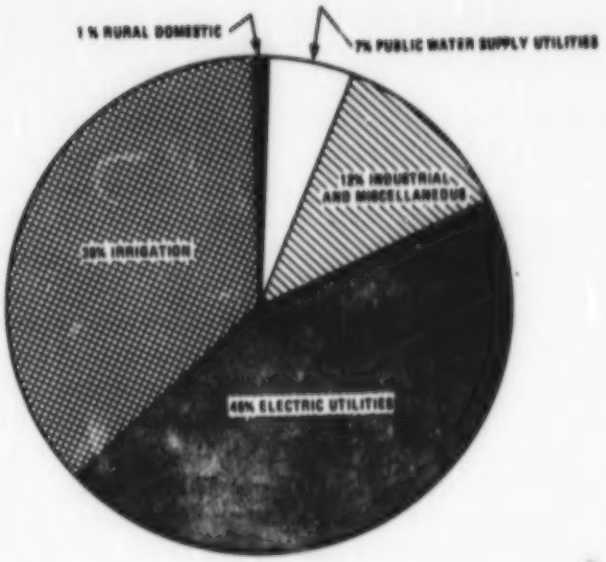
The total U.S. water consumption for 1970 was 370 billion gallons per day.[1] The largest water use in this country was for hydroelectric power generation and accounted for 45 percent of the total water use. Irrigation accounted for 35 percent of the water use, and industrial water use accounted for 12 percent of the total U.S. water use (fig. 1). Eighty percent of the industrial water use was concentrated among four industries (fig. 2). The water used by public water supply utilities accounted for only 7 percent of the total U.S. water use (fig. 1). Seventy percent of the household water use was for toilet flushing and bathing (fig. 3). The water used by public water supply utilities and industrial processes amounted to only 19 percent of the total U.S. water use. The public utilities and industrial water use is directly related to the quantity of wastewater requiring treatment under the Federal Water Pollution Control Act Amendments of 1972 and is the subject of this report.

Data from the Environmental Protection Agency's 1973 "Needs" survey for municipal wastewater treatment facilities indicated a total wastewater flow of 17,841 million gallons per day for the 7,605 reporting municipalities. The survey data indicated that 20 percent of this wastewater was from industrial sources. The survey did not determine the wastewater distribution between domestic sources and infiltration/inflow sources (fig. 4).

Attempts to forecast levels of future water use and wastewater production on the basis of past data are impractical and undesirable. Future water use and wastewater production will depend largely on the growth rate of the population and the economy plus adopted public policies. User charges designed to equitably recover the costs of water supply and wastewater treatment will significantly influence future projections. Industrial wastewater recycle/reuse trends have recently been increasing, but these trends may accelerate in the near future because of limited water supply, poor water quality, and other environmental considerations.

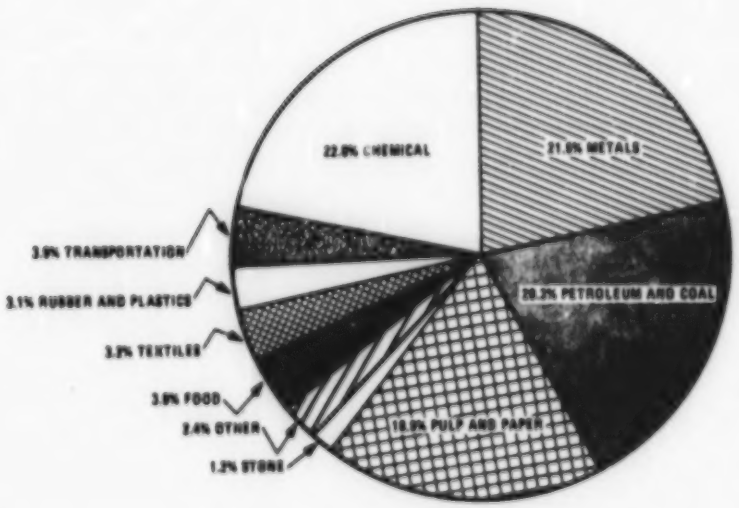
The National Water Commission[1] estimated the total U.S. water use in the year 2000 may range from 570 to 2,280 billion gallons per day, depending on the combination of assumed variables. The Environmental Protection Agency's "Needs" survey indicated that wastewater flow for the reporting municipalities would double by the year 1990, but this estimate was based only on past data and did not consider the impact of present Federal and State regulations, pricing policies, and other variables.

Preceding page blank



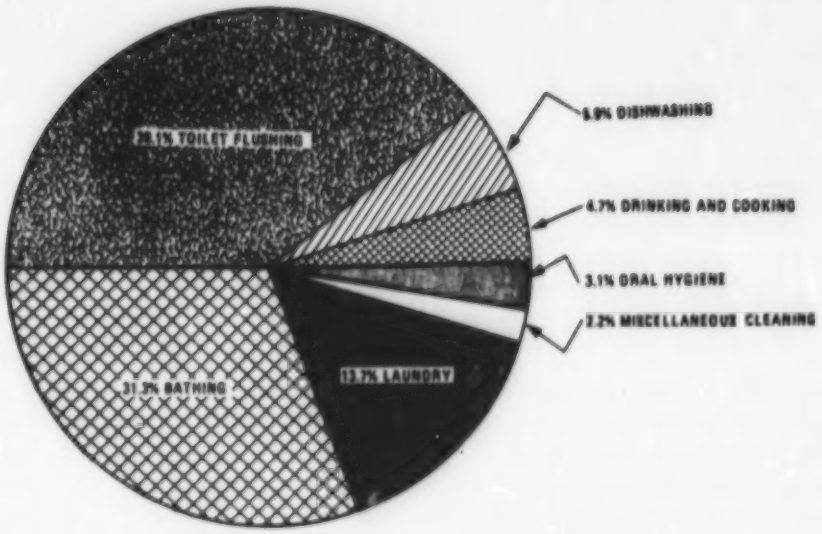
TOTAL: 370 BILLION GALLONS PER DAY

Figure 1. Water Use.



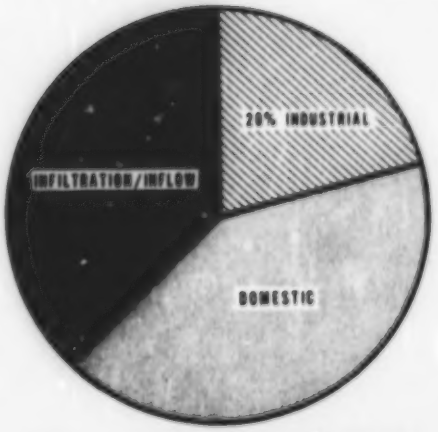
TOTAL: 36.8 BILLION GALLONS PER DAY

Figure 2. Industrial Water Use.



TOTAL: 64 GALLONS PER CAPITA PER DAY

Figure 3. Household Water Use.



TOTAL: 17,841 MILLION GALLONS PER DAY

Figure 4. Municipal Wastewater.

Implementation of the Federal Water Pollution Control Act Amendments of 1972 will require large capital investments by Federal and State governments, local municipalities, and industries for wastewater collection and treatment. The Environmental Protection Agency's 1973 "Needs" survey estimated a total of $80.1 billion for the construction of new municipal wastewater treatment facilities. This level of investments in wastewater treatment requires that flow reduction methods be evaluated and cost-effectively incorporated in the design of wastewater treatment works. However, cost-effective determinations for wastewater flow reduction are dependent on the costs of wastewater treatment and water supply, which are presently very low in most areas of the United States. Wastewater treatment costs are expected to increase in the future because of the requirements for higher levels of wastewater treatment.

Wastewater flow-reduction programs have to be determined on the basis of specific flow-reduction objectives. The reduction of flows in wastewater treatment systems can often reduce the investments needed for the construction and operation of wastewater treatment works and, at the same time, contribute to the conservation of our Nation's limited water resources. Long-range programs of wastewater flow reduction may extend the useful life of wastewater treatment works since expansion of wastewater facilities may be avoided if wastewater flow-reductions methods are used to compensate for the increased wastewater flows generated by population and industry growth.

Wastewater flow reduction can be accomplished through reduction of infiltration and inflow in sewer systems, reductions in household water use, industrial wastewater recycle/reuse, and realistic economic policies. The report discusses the potential for wastewater flow reduction in these areas.

WASTEWATER FLOW-REDUCTION STUDIES

The three major components of municipal wastewater are infiltration/inflow, domestic wastewater (household and commercial), and industrial wastewater (fig. 4). The EPA "Needs" survey indicated 20 percent of the reported municipal wastewater was from industrial sources, but the survey was unable to determine the distribution between domestic wastewater and infiltration/inflow.

INFILTRATION/INFLOW

The amount of infiltration/inflow or extraneous water entering a sewer system is represented by the difference between the maximum domestic and industrial wastewater flows produced by a community and the total sewage flow in a sewer system. Infiltration occurs when existing sewerlines are undergoing material and joint degradation and deterioration as well as when new sewerlines are poorly designed and constructed. Inflow normally occurs when rainfall enters the sewer system through direct connections such as roof leaders and catch basins.

Data accrued as part of the EPA regulations for treatment works construction grants indicates that infiltration/inflow frequently constitutes a significant portion of the total municipal wastewater. The following examples of separate sanitary sewer systems illustrates the distribution of infiltration/inflow in some municipal wastewater.

In California a 600 million-gallon-per-day (mgd) wastewater treatment system has 18 percent of its flow composed of infiltration/inflow. In Wisconsin, one wastewater treatment system of 38 mgd has 76 percent of its flow composed of infiltration/inflow, while another system of 39 mgd has only 0.7 percent of its flow composed of infiltration/inflow. In the State of New York, a 70 mgd system has 80 percent of its flow composed of infiltration/inflow.

The following is a description of EPA studies which have been related to infiltration/inflow.

Tulane University: The Environmental Protection Agency participated with Tulane University[2] in ground water evaluation studies on several sewer systems in the Gulf Coast area during 1962 and 1963 and again during 1970 to compare the changes in the infiltration. Measurements of infiltration in the systems ranged from zero to 111,560 gallons per inch of diameter per mile per day. During the study period the infiltration increased slightly in some sewerlines and decreased greatly in others. The decrease was attributed to soil and grease clogging of sewer breaks. This conclusion was supported by subsequent television inspections of the sewers. High infiltration rates were attributed to poor construction methods for the sewer system and house connections. Poor construction procedures were considered to be the most significant contributors to infiltration and sewer failure.

When sewers are constructed in areas of high ground water, sewer bedding containing such expanding clay materials as bentonite or portland cement mixed with granular

materials tends to reduce the ground water flow along the sewer trench bottom and reduces the effects of sewer undermining when infiltration develops.

Sewer Sealants: The Environmental Protection Agency participated in a laboratory program with the Weston Co.[3] to develop new and more effective sealants for eliminating infiltration leaks in sewers. Four epoxy-based sealants and two urethane-based sealants were developed that could produce strong, permanent repairs. These new sealants are suitable for eliminating infiltration under repeated dehydration conditions which cause failure of the existing acrylamid gel sealants. Equipment for applying the new sealants could be designed at costs approximately equal to existing equipment. However, existing sealant equipment could be modified to handle the new sealants. The costs for the new sealants would not significantly increase the costs of infiltration correction in sewer systems.

Montgomery County: The Environmental Protection Agency participated in a program with the Montgomery County, Ohio, Sanitary Department[4] to study the effects of infiltration reduction by internal sealing of sewer joints and to study closed circuit television techniques for identification of infiltration. Each sewer joint in the study area was pressure tested for failure and pressure grouted with an acrylamid sealant when the joint did not maintain the prescribed pressure level. The internal pressure sealing process was successful in eliminating ground water infiltration into the sewerlines. Television inspection of the sewerlines revealed many pipe defects that were not apparent through smoke testing. Thus before grouting sewer joints, the actual condition of sewerlines should be determined through television inspection.

The study concluded to successfully reduce sewage flows a sewer joint sealing program for infiltration reduction must include a detailed study of the sewage flows and a program for inflow reduction.

Sewer Joints: The Environmental Protection Agency participated in laboratory studies with the Weston Co.[5] to couple sewer pipes in tight waterproof joints using the heat-shrinkable plastic tubing developed and used extensively in the electronics and aerospace industries. Laboratory studies of such materials and joints were conducted to determine their characteristics and their operational and economic feasibility. A polyolefin with a polymeric-base, hot-melt adhesive produced the most durable, watertight joints and was significantly superior in performance compared to existing pipe-jointing mechanisms. A cost analysis indicated that the heat-shrinkable plastic joints were economically feasible and compared favorably to conventional sewer joints when considering both material and installation costs.

American Public Works: The Environmental Protection Agency sponsored a national study by the American Public Works Association[6,7] to identify the sources and methods for control of infiltration and inflow plus develop a manual of practice for evaluating sewer construction practice, conducting surveys to determine the extent and location of infiltration and inflow, conducting economic analyses of the cost of excessive infiltration/inflow, and instituting corrective action. The study was also supported by 39 public agencies.

The Association conducted a comprehensive survey of municipalities, State water pollution control agencies, consulting engineers, contractors, and related industrial firms. The survey found infiltration and inflow to be a widespread problem.

The manual of practice discusses the design and construction factors which are involved in the control of infiltration in new sewers, such as soil and ground water conditions, types of sewer pipes and joints, infiltration design allowances, construction bedding and backfilling, and infiltration acceptance testing.

The manual details a systematic approach for the identification of infiltration and inflow to avoid the ineffectual and costly results of a haphazard deployment of investigative devices and equipment.

The first step in the recommended approach would be to identify and evaluate the infiltration/inflow to determine if a problem exists and to justify a detailed study of the problem. A detailed evaluation of the infiltration/inflow would involve identification of the physical characteristics of the sewage systems, flow measurements, rainfall simulation, and sewer cleaning followed by internal inspection of the sewerlines to specifically locate the sources and magnitude of the infiltration/inflow. After the specific identification of the infiltration/inflow sources, an economic analysis would be conducted to determine which sources of infiltration/inflow warranted correction. This procedure is similar to the Environmental Protection Agency's regulations for infiltration/inflow.

DOMESTIC WASTEWATER

Since the public has long viewed the supply of water as inexpensive and inexhaustible, the public's attitude toward water conservation and consumption is an important consideration in any reduction program. A 1969 survey by the General Dynamics Corp. of a selected group of people indicated a lack of public acceptance of flow-reduction devices which have high initial costs, require operational maintenance, and lack esthetic appeal.

The following is a description of projects which have been conducted to demonstrate and evaluate the use of water-saving devices in the household.

Household Flows: The Environmental Protection Agency participated in a study conducted by General Dynamics to typify the average household water requirements for a family of four. The "model" home was assumed to consist of three bedrooms and one and one-half bathrooms with a shower and tub or a shower-tub combination, an automatic washing machine, a dishwasher, and a garbage disposal unit. Water for household uses was estimated at 15 gallons per day (gal/d) for dishwashing, 35 gal/d for laundry, and 5 gal/d for miscellaneous cleaning. The water required for personal uses was estimated at 50 gal/d per person: 3 for drinking and cooking, 20 for bathing, 2 for oral hygiene, and 25 for toilet flushing. Thus, a total of 255 gal/d, an average of 64 gallons per capita per day, was determined. These data are presented graphically in figure 3.

The study evaluated several toilets. A dual-cycle toilet with one flush cycle for urine, using 1¼ gallons, and the other cycle for solid wastes, using 2½ gallons per flush, was tested.

This device could provide a 70- to 75-percent reduction in flushing water use (29 percent of total per capita water use) when compared with the 5 to 6 gallons per flush required in the standard toilet. Shallowtrap toilets with improved tank design deliver only about 3.5 gallons per flush. Batch-type flush valves, presently used in commercial buildings, could also be used in the home in lieu of toilets. They can be set to deliver from 0.5 to 4 gallons per cycle. However, they require a larger diameter waterline than the standard flush tank. Thus, their potential would be limited to new home construction. The Liljendahl (Swedish) vacuum toilet system uses air rather than water as the prime transport medium. It requires only 0.5 gallon of water per flush. Plastic pipe (2-in. diameter) is used for the drain lines, and a waste-receiving tank and vacuum pump are needed. This system has been used in apartment houses, but not in individual homes.

Flow-reduction devices are currently available for shower heads and faucet fittings. The flow rates for showers are usually restricted to about 3 gal/min, which manufacturers claim results in a water savings of 50 to 70 percent. However, the quantity of shower water saved will be dependent on many factors, including the available water pressure and habits of the user. Faucet fittings usually restrict flows to 2.5 gal/min for each valve. A very simple water-saving device in wide use is the faucet aerator. It is estimated that the aerator reduces water consumption by approximately 25 percent. A faucet thermostatic mixing valve permits the mixing of hot and cold water to attain a desired temperature level and offers moderate savings in water consumption. It avoids the problem of "flushing" the cold water from the hot water lines while waiting for the desired water temperature. A recently developed faucet device features a complete unit to control flow rates and temperature electrically. Push buttons located on or near the water tap trigger a valve on the hot water line adjacent to the hot water tank which regulates the amount of hot water used. A single 1/4- or 3/8-inch supply line reduces the amount of cold water flushed from the line. The manufacturer claims up to a 15-percent total household water reduction with the device.

An advantage of faucet and shower flow-reduction devices is their savings in fuel for hot water. A fuel costs reduction of the same order of magnitude as the total water savings costs can often be realized.

Automatic clothes washers vary in their water requirements from about 20 to 33 gallons per cycle. One feature used in automatic washing machines to save water and detergent has been to store and reuse the wash water. However, this feature has not proved popular with the consumer. Front-loading washers use approximately one-half as much water for a particular load size as top-loading washers. Again, however, customer acceptance has been poor.

The report drew the following conclusions:

1. Limited flow shower heads appear to be justified and should be further considered.

2. The vacuum flush water closet can only be justified (economically) for groups of homes or multifamily dwellings.

3. Of the various water closets and urinals considered, the dual-cycle water closet appears to be the best approach for sanitary waste and should be further considered.

4. Aerator faucets, where not already in use, should be required.

5. The other plumbing devices listed do not appear to be warranted.

The report developed the following rating for water-saving devices in *decreasing* order of water savings and net yearly dollar savings:

1. Shallow-trap toilets
2. Flow-control showers
3. Two-flush valves with toilet
4. One-flush valves with toilet
5. Aerators
6. Reuse of wash water for toilet flushing
7. Aerobic treatment of wastewater
8. Distillation and reuse of all wastes

The report further concluded that water savings of 50 gal/d per home can be realized by using just the first five devices listed above. These five devices are available commercially; relatively easy to install; require minimum homeowner maintenance; and if cost-effectively justified, could provide substantial water savings to the homeowner.

Household Demonstrations: The Environmental Protection Agency participated in a demonstration program with General Dynamics[8] to evaluate various water-saving devices and recycle/reuse systems. Eight homes were chosen in the Groton, Conn., and San Diego, Calif., areas, and each home was metered to determine actual water use before, during, and after the testing program. Reduce-flow toilets, both shallow-trap and those modified for dual-flush, and flow-restricting shower heads were evaluated. The recycle/reuse systems studied the use of both a diatomite and a cartridge filter system to treat bath and laundry wastewater for use as a toilet and lawn irrigation water source. The results of the testing program can be summarized as follows:

- Shallow-trap toilets resulted in an average decrease of 25.6 percent in flush water used and of 6.9 percent in total home water use.

- Dual-flush toilets resulted in an average decrease of 22.6 percent in flush water used and of 6 percent in total home water use.

- Limited-flow shower heads reduced bath water used by 7.5 percent and total home water use by 1 percent.

- Where wash-water (bath and laundry) recycle systems were used for toilet flushing and lawn watering, the average decrease in total home water use was 27 percent.

Estimates based on the cost of water saved indicate that the reduced-flow toilets and shower heads are economically attractive for individual homeowners. Wash-water recycle

systems can be justified for the home if both the cost of water and wastewater treatment are considered. This indicates that more experimental work on recycle systems for single homes can be beneficial. Recycle systems for multiple dwellings should be even more attractive.

Washington Suburban Sanitary Commission: On October 29, 1971, the Washington, D.C., Suburban Sanitary Commission[9] adopted a policy to promote public water conservation and to reduce wastewater flows in Montgomery and Prince Georges Counties, Md. The Commission approved a demonstration program for the Cabin John Drainage Basin in Montgomery County, Md., to install and test water-saving devices such as water-closet inserts, pressure-reducing valves, and flow controllers. The program involved the placement of approximately 4,800 flow-reduction devices in 2,400 dwelling units within the Cabin John Drainage Basin and represented about 11 percent of the dwelling units in the basin. All large apartment developments, a number of townhouses, and 1,200 single-family homes were involved in the program.

The results are summarized as follows:

- Toilet Inserts (water-displacement devices)
  - Apartment units. Of the four apartment units in the program two units showed decreases of 12 percent (25 gal/d per unit) and 16 percent (44 gal/d per unit) in water consumption. The other two units showed water consumption increases of from 3.5 to 140 percent. When the property owner was responsible for adjustment and maintenance, the use of toilet inserts was not satisfactory.
  - Single-family units. Water consumption reduction by using toilet inserts ranged from 13.5 to 26 percent, or 37 to 38 gal/d per unit.

- Pressure-Reducing Valves. Pressure-reducing valves were installed in 83 single-family homes where incoming water pressure ranged from 70 to 120 lb/in.^{2} With a pressure reduction to 50 lb/in.^{2} and the use of toilet inserts, water consumption was reduced 30 to 37 percent (115 gal/d per unit).

- Shower Flow-Control Devices. Shower head flow-control devices with a 3.0 gal/min flow rate were installed in 25 single-family homes. Approximately a 12-percent (30 gal/d per unit) reduction in water consumption was achieved by these devices. The percentage of water reduction is significantly higher than the 1-percent value reported in the earlier study by General Dynamics. This may be due in part to a large sample size, personal habits, or time of sampling.

Housing and Urban Development: A research and demonstration program conducted by the Department of Housing and Urban Development[10] that relates to the reduction of household water use is the modular integrated utility system (MIUS). The overall objectives of the MIUS program are to:

- Provide electricity, environmental conditioning (heating and/or air conditioning), water and waste treatment disposal, and distribution networks for these services in an improved manner with advantages of total cost, decreased environmental impact,

and increased efficiency in the utilization of natural resources

- Provide these services at a rate equal to the rate of growth of new developments, such as new communities, additions to existing ones, and large-scale redevelopment in present population centers

- Make land that is not being serviced by conventional utility systems available for development

The MIUS program is presently being conducted and involves the Atomic Energy Commission, the National Aeronautics and Space Administration, the National Bureau of Standards, the National Science Foundation, the Department of Defense, the Environmental Protection Agency, and the National Academy of Engineering. The results of this MIUS program are not available for inclusion in this report.

Wainright, Alaska: The Environmental Protection Agency conducted a demonstration program in Wainright, Alaska,[11] to provide a water supply program and wastewater treatment system in an area of limited water supply and wastewater treatment capabilities.

Recirculating chemical toilets similar to those used on jet aircraft were the primary water-saving devices. The toilets use a very small amount of water that is recirculated for about 50 uses. The toilets are evacuated periodically by vacuum sewers and the contents incinerated with the solid refuse generated in the village. The incinerator waste heat was utilized for space heating. The toilets were recharged with treated wastewater from the laundry and showers.

Flow-limiting orifices and timers coupled with flow switches were used to control volume of water used in the showers. The shower flows were limited to 2 gal/min for 2½ minutes. Saunas, supplied by waste heat from the incinerator, provided an additional water savings because their utilization as a "soak" normally provided extended use of showers.

INDUSTRIAL WASTEWATER

The Federal Water Pollution Control Act Amendments of 1972 requires industrial wastewater point sources to utilize the best available technology economically achievable by July 1, 1983, which will result in progress toward the total elimination of pollutant discharges. To economically meet the 1983 requirements most industries will have to consider recycling and reusing a large portion of their present wastewaters. With increasing requirements for higher levels of wastewater treatment, industries will probably increase the recycle/reuse of their wastewaters until the industrial water intake requirements equal the process water evaporation and the product water consumption.

The Environmental Protection Agency has been able to conduct only limited research and investigations in the area of industrial wastewater flow reduction, since the recycle/reuse of industrial wastewaters usually involves major process equipment changes at costs which are substantial in relationship to the Agency's research and development funds. The ferroalloys, steel, and petroleum industries are three examples of major water-using

industries which the agency has not been able to materially assist in the development of wastewater recycle/reuse technology. However, these and other industries have conducted some wastewater recycle/reuse research, and in a few instances the industries have implemented recycle/reuse procedures. This report does not include independent industrial wastewater recycle/reuse research and practices conducted by the various water-using industries. The complete results of industrial wastewater flow-reduction research and investigations will be reported to the Congress after promulgation of the Industrial Effluent Limitations Guidelines and New Source Performance Standards required by the Federal Water Pollution Control Act Amendments of 1972. The following industrial wastewater flow-reduction studies were jointly conducted by the Environmental Protection Agency and various industrial firms.

Brass and Copper: The EPA participated in the installation of a continuous electrolytic system at the Volco Brass and Copper Co.[12] to recover copper from the primary pickle solution and regenerate the sulfuric acid used in the pickle solution. The conventional chromate and fluoride bright pickles were replaced with a hydrogen peroxide bright pickle. A chemical rinse solution of caustic soda, soda ash, and a reducing agent was installed ahead of the water rinse. The rinse waters were adjusted for pH and hardness prior to recirculation to the pickle line. The combined effects of chemical rinsing and water reuse resulted in a 93-percent reduction of the wastewater discharge. The primary pickle bath, formally disposed of monthly, and the bright pickle bath, formally disposed of weekly, do not require disposal under the new system. The new system substantially reduced wastewater treatment and disposal costs.

Chemical: The EPA participated in a demonstration plant which was constructed and operated by the Dow Chemical Co.[13] to examine the feasibility of removal and recovery of phenol and acetic acid from an 18-percent sodium chloride brine by adsorption on fixed beds of activated carbon. The purified sodium chloride brine was used for production of chlorine and caustic soda. The recovered phenol was used in the phenol manufacturing plant, and the regenerated acetate was disposed of in underground wells. The study successfully demonstrated the reuse of waste sodium chloride brines to manufacture chlorine and caustic soda.

Paper: The EPA participated in the installation of a cooling-tower barometric condenser system at Georgia Kraft Co.[14] to evaluate the feasibility of using cooling towers to reduce the biochemical oxygen demand (BOD) and heat content of selected kraft mill effluents and to limit the water use in kraft mills.

Wastewaters from the evaporator systems, decker filtrate, and turpentine decanter underflow were cooled in the tower and reused as water for the barometric condensers. The tower removed about 25 to 30 percent of the entire organic pollution load discharged from the mill. The cooling-tower system produced approximately a 45-percent reduction in the mill's total water requirement. The operation and capital costs of the system are less than other wastewater treatment systems.

Pulp and Paperboard: The EPA participated in part of a program by Green Bay Packaging[15] to establish a closed-loop recycle/reuse system for its pulp and paperboard

wastewaters. The EPA phase of the program involved a pilot study to determine the feasibility of using the reverse osmosis process to concentrate dilute wastewaters and to reuse the recovered wastewater in the manufacturing process.

The study demonstrated the reverse osmosis process could be applied to pulp and paper wastewaters. The process can result in a 90-percent reduction in the volume of dilute wastewaters. The reverse osmosis equipment was capable of processing the wastewater with reasonable efficiency. The costs of the reverse osmosis process were about equal to the costs of regular wastewater treatment of the dilute wastewaters. The recovered wastewaters were acceptable for use in the wire-cleaning showers in the paper machines and for several other minor uses.

Fiber: The EPA participated in demonstration studies conducted by Fiber Industries and Davis and Floyd Engineering[16] to determine the feasibility of reusing the wastewater from a Fortrel polyester manufacturing plant. The wastewater contained organic chemical process wastes, cooling system blowdown, and domestic wastewaters from the plant. The study involved upgrading the existing wastewater activated-sludge process to reuse the effluent. The wastewater was treated with sulfur dioxide in an acidic environment to remove chromium. A plastic media roughing filter was added to increase BOD removal. A microscreen plus polymers and/or carbon was used to remove color, chemical oxygen demand, and dissolved and suspended solids. The study successfully reused 30 percent of the plant's wastewater for cooling-tower makeup and other selected uses.

Fiberglass Insulation: The EPA participated in the development of a closed-loop process for Johns-Manville's fiberglass insulation[17] plants to eliminate the discharge of phenolic resin wash waters originating from the fiberglass collecting conveyors. The process consists of low-volume, high-pressure conveyor cleaning units, two stages of primary filtration to remove large particles and fibers, and secondary diatomite filters to remove fine particulate matter. The filtered water is reused in the fiberglass-manufacturing process. Water is reused 4½ times before it is removed from the closed system by evaporation. The closed-loop system eliminates wastewater discharges and their associated treatment. The system also produces substantial operation savings by conservation of binder resins and purchased water supplies.

PROGRAMS

The authority granted to the Environmental Protection Agency by the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) will have a significant effect on sewage flows and water consumption. Although no section of the Act specifically requires the reduction of sewage flows and unnecessary water consumption, several sections provide indirect opportunities for wastewater flow reductions. These sections are:

201(g)(2) – Alternative Waste Management Techniques

201(g)(3) – Excessive Infiltration/Inflow

204(b) – Users Charges and Industrial Cost Recovery

212(2)(C) – Cost Effectiveness

304(d)(2) – Information on Alternative Waste Treatment Management Techniques

304(b) – Effluent Guidelines (for point sources other than publicly owned treatment works)

306 – National Standards of Performance (New Sources)

307(b) – Pretreatment Standards for Existing Sources

307(c) – Pretreatment Standards for New Sources

In the development of the regulations and guidelines required by these sections of the Act, the Environmental Protection Agency made a concerted effort to promote wastewater flow reduction. A brief description of the above sections of the Act and their potential for wastewater flows reduction is presented below:

Section 201(g)(2) requires grant applicants to demonstrate that alternative waste management techniques have been studied and evaluated so that the proposed treatment works will provide the best practicable waste treatment technology. When appropriate, the proposed treatment works would also take into account and provide for the future application of technology which would provide for the reclaiming or recycling of water or otherwise eliminate the discharge of pollutants.

The Environmental Protection Agency developed guidelines for facilities planning which describe the factors to be considered in the selection and evaluation of alternative waste treatment systems. The guidelines discuss various waste treatment systems, including wastewater flow-reduction measures, which are considered to be acceptable waste management alternatives.

Section 201(g)(3) requiring that "the Administrator shall not approve any grant after July 1, 1973, for treatment works unless the applicant shows . . . that each sewer collection system discharging into such treatment works is not subject to excessive infiltration." To implement this requirement the Environmental Protection Agency has issued guidelines and regulations which define excessive infiltration/inflow and outline the steps which must be taken to eliminate it.

Preceding page blank

These regulations also provide for future reductions of infiltration/inflow by requiring the enactment and enforcement of a sewer use ordinance which will prohibit new inflow sources in sanitary sewers and insure the proper design and construction of new sewers.

Section 204(b) requires treatment works grant applicants to adopt a system of user charges to assure that each recipient of waste treatment services will pay his proportionate share of the operation and maintenance (including replacement) costs for such waste treatment services. The section also requires industrial users to repay the Federal share of the construction costs for the portion of the treatment works required for industrial waste treatment. The user charges and industrial costs recovery regulations published by the Environmental Protection Agency should stimulate wastewater flow reduction since the costs of wastewater treatment services will be directly related to wastewater production. A discussion of water supply pricing policies is presented in appendix B of this report.

Section 212(2)(C) authorizes the Environmental Protection Agency to publish guidelines grant applicants must follow to demonstrate that the proposed treatment works will be the most cost-effective waste treatment alternative that achieves Federal, State, and local standards for effluent quality, water quality, water reuse, and/or land and subsurface disposal. The guidelines apply to alternative waste management techniques and systems discharging to receiving waters, using land or subsurface disposal techniques, and employing the reuse of wastewater. Through the evaluation of the total wastewater treatment costs, the guidelines should economically stimulate wastewater flow reduction. Examples of cost-effectiveness analyses are contained in appendix A of this report.

Section 304(d)(1) requires information on the degree of effluent reduction attainable through the application of secondary treatment. The information published by the Environmental Protection Agency specifies an 85-percent minimum level removal of BOD and suspended solids. This level of wastewater treatment should stimulate the concentration of dilute wastewaters by various flow-reduction methods.

Section 304(d)(2) requires information on alternative waste treatment management techniques and systems. The information published by the Environmental Protection Agency divided alternative waste management techniques and systems into three categories: (1) treatment and discharge into navigable waters, (2) land application techniques and (3) wastewater reuse. Information was provided for the application of best practicable waste treatment technology for each of the three waste management techniques. The use of wastewater flow-reduction devices is a recognized technique under the waste management alternatives for treatment and discharge into navigable waters.

Section 304(b) requires effluent limitations which set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best achievable control measures, practices, treatment techniques, process and procedure innovation, operation methods, and alternatives for point sources other than publicly owned treatment works.

Section 306 requires a Federal effluent standard for new sources that reflects the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

To fulfill the requirements of Sections 301, 304(b) and 306 of the Act, the Environmental Protection Agency published jointly effluent limitations for both existing and new point sources. These point sources were divided into the following 30 categories:

1. Pulp, paper, and paperboard mills
2. Builders' paper and board mills
3. Meat product and rendering processing
4. Dairy product processing
5. Grain mills
6. Canned and preserved fruits and vegetables processing
7. Canned and preserved seafood processing
8. Beet sugar processing
9. Cane sugar processing
10. Textile mills
11. Cement manufacturing
12. Feedlots
13. Electroplating
14. Organic chemicals manufacturing
15. Inorganic chemicals manufacturing
16. Plastics and synthetic materials manufacturing
17. Soap and detergent manufacturing
18. Fertilizer manufacturing
19. Petroleum refining
20. Iron and steel manufacturing
21. Nonferrous metals manufacturing
22. Phosphate manufacturing
23. Steam electric powerplants
24. Ferroalloy manufacturing
25. Leather tanning and finishing
26. Glass manufacturing
27. Insulation fiberglass manufacturing
28. Timber products processing
29. Asbestos processing
30. Rubber processing

The effluent limitations established for these industrial categories will frequently require industries to modify or change processes, such as the conversion of wet air scrubbers to air bags for air pollution control. Industry will often be required to recycle and reuse its wastewater, and in some instances, it will be required to discharge zero pollutants. These effluent limitations should definitely have a significant impact on the reduction of industrial wastewater flows and water consumption.

Section 307(b) requires the establishment of pretreatment standards for pollutants introduced into publicly owned treatment works. The standards restrict the discharge of pollutants which are not compatible, or would interfere, with the operation of the publicly owned treatment works.

Section 307(c) requires pretreatment standards for new sources introducing pollutants into a publicly owned treatment works. Such pretreatment standards would prevent the discharge of any pollutant which may interfere with the treatment process or otherwise be incompatible with the treatment works.

To fulfill the requirements of Sections 307(b) and 307(c), the Environmental Protection Agency published standards which require pretreatment of incompatible pollutants to the levels of best practicable control technology currently available as defined in the guidelines for industrial categories published pursuant to Section 304(b) of the Act. The pretreatment standards should significantly impact industrial wastewater flows to publicly owned treatment works since many of the practicable control technologies currently available utilize flow-reduction procedures to control pollutant discharges.

FUTURE RESEARCH EFFORTS

The Environmental Protection Agency is planning to evaluate the infiltration/inflow data acquired as part of its construction grant program to accurately define the scope of the infiltration/inflow problem and the cost of infiltration/inflow correction. These data will also be used to develop further guidance for engineers, municipalities, and regulatory agencies for the evaluation of infiltration/inflow in sewer systems.

Since the household wastewater flow-reduction devices currently available can effectively reduce household flows, further research and development in this area should be conducted by the manufacturers of such household flow-reduction devices. The Environmental Protection Agency plans to study the institutional problems encountered in establishing household flow-reduction programs.

The Environmental Protection Agency and various industries are jointly conducting research to advance and demonstrate industrial water pollution control technology through byproduct recovery and wastewater reuse processes. The following is a list of research and development or demonstration projects being conducted by the Environmental Protection Agency and various organizations and industrial companies to reduce wastewater flows:

- Production and Use of Activated Carbon for Water Renovation at Kraft Pulp and Paper Mills (St. Regis Paper Co.)

- Hartig Pond Closing System—Phosphate Chemical Plants (State of Florida Department of Air and Water Pollution Control)

- Water Reuse in a Paper Reprocessing Plant (Big Chief Roofing Co.)

- Aerobic Biological Treatment, Sludge Dewatering and Disposal, and Effluent Reuse for a Side Leather Tannery (S. B. Foot Tanning Co.)

- Leather Tannery Waste Management Through Process Change, Reuse, and Pretreatment (Pfister & Vogel Tanning Co.)

- Treatment of Coke Plant Waste Liquor (Alan Wood Steel Co.)

- Pollution Control of Blast Furnace Gas Washer Through Recirculation (Interlake Steel Corp.)

- Elimination of Biocides in Cooling Tower Blowdown by Use of Ozone (General Telephone Co. of California)

- Closed Process Water—Loop in NSSC Pulp Production (Green Bay Packaging)

- Treatment of Oil Refinery Wastewater for Reuse Using a Sand Filter-Activated Carbon System (B. P. Oil Corp.)

- Ecostatic Cane Processing System (Hilo Coast Processing Co.)

- Management of Recycled Waste-Process Water Ponds (Johns Hopkins University)

- Recovery and Reuse of Synthetic Size from Textile Finishing Wastewaters (North Carolina State University)

- Treatment and Reuse of Textile Dyehouse Wastewaters Using Reverse Osmosis (La France Industries)

REFERENCES

1. *Water Policies for the Future,* Final Report to the President and to the Congress of the United States by the National Water Commission, Washington, D.C., (June 1973).

2. *Sewer Bedding and Infiltration Gulf Coast Area,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 11022 DE1 05/72 (May 1972).

3. *Improved Sealants for Infiltration Control,* Federal Water Pollution Control Administration, Water Pollution Control Research Series, WP-20-18 (June 1969).

4. *Ground Water Infiltration and Internal Sealing of Sanitary Sewers,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 11020 DHQ 06/72 (June 1972).

5. *Heat Shrinkable Tubing as Sewer Pipe Joints,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 11024 FLY06171 (June 1971).

6. *Control of Infiltration and Inflow into Sewer Systems,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 11022 EFF 12/70 (Dec. 1970).

7. *Prevention and Correction of Excessive Infiltration and Inflow in Sewer Systems, A Manual of Practice,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 11022 EFF 01/71 (Jan. 1971).

8. Bailey, J. R., and Cohen, S., "Demonstration of Waste Flow Reduction from Households," General Dynamics, Electric Boat Division, EPA Contract No. 68-01-0041 (compilation of progress reports, latest dated June 1973).

9. The Washington, D.C., Suburban Sanitary Commission, "Final and Comprehensive Report, Cabin John Drainage Basin, Water-Saving Customer Education and Appliance Test Program" (Feb. 1973).

10. Department of Housing and Urban Development, Office of Research and Technology, "Modular Integrated Utility System (MIUS), Program Description" (Dec. 1972).

11. "Alaska Village Demonstration Projects," Report to Congress, prepared by the Office of Research and Development, U.S. Environmental Protection Agency (July 1, 1973).

12. *Brass Wire Mill Process Changes and Waste Abatement, Recovery and Reuse,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12010 DPF 11/71 (Nov. 1971).

13. *Recondition and Reuse of Organically Contaminated Sodium Chloride Brines,* U.S. Environmental Protection Agency, Environmental Protection Technology Series, EPA-R2-73-200 (May 1973).

Preceding page blank

14. *Treatment of Selected Interval Kraft Mill Wastes in a Cooling Tower,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12040 EER. 08/71 (Aug. 1971).

15. *Recycle of Papermill Waste Waters and Application of Reversed Osmosis,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12040 FOB01/72 (Jan. 1972).

16. *Reuse of Chemical Fiber Plant Wastewater and Cooling Water Blowdown,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12090EOX10170 (Oct. 1970).

17. *Phenolic Waste Reuse by Diatomite Filtration,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12080 E2F 99/70 (Sept. 1970).

18. Hirshleifer, J.; De Haven, J. C.; and Milliman, J. W. *Water Supply: Economics, Technology and Policy.* Chicago: University of Chicago Press (1960).

19. Howe, C. W., and Linaweaver, F. P., Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure." *Water Resources Research* 3(1) (1st quarter 1967).

20. Fair, G. M.; Geyer, J. C.; and Okus, D. A., *Water and Wastewater Engineering,* vol. 1, *Water Supply and Wastewater Removal.* New York: John Wiley & Sons, (1966).

21. Davis, R. C., and Hanke, S. H., "Pricing and Efficiency in Water Resource Management," George Washington University, for the National Water Commission (Dec. 1971).

22. Gysi, M., "The Effect of Price on Long Run Water Supply Benefits and Costs," Water Resources Bulletin, *Journal of the American Water Resources Association,* 7(3) (June 1971).

23. Mann, P. C., "Water Service Prices: A Principal Component and Regression Analysis of Determinants," Regional Research Institute, West Virginia University, prepared for Office of Water Resources Research, Project No. C-2012 (July 1972).

24. Mayer, J. C., Macdonald, F. W., and Steimle, S. E., "Sewer Bedding and Infiltration Gulf Coast Area," Tulane University, EPA Contract No. 80-04-68 (May 1972).

25. American Public Works Association, "Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems—A Manual of Practice," EPA Contract No. 14-12-550 (Jan. 1971).

26. Schmidt, O. J., "Pollution Control in Sewers," *Journal of the Water Pollution Control Federation* 44(7) (July 1972).

27. The Western Company of North America, "Heat Shrinkable Tubing as Sewer Pipe

Joints," EPA Contract No. 14-12-854 (June 1971).

28. Bremner, R. M., "In-Place Lining of Small Sewers," *Journal of the Water Pollution Control Federation* 43(7) (July 1971).

29. Carcich, I. G., Farrel, R. P., and Hetling, L. J., "Pressure Sewer Demonstration Project," *Journal of the Water Pollution Control Federation* 44(2) (Feb. 1972).

30. Brown, K. W., and Caldwell, D. H., "New Techniques for the Detection of Defective Sewers," *Sewage and Industrial Wastes* 29 (1957).

31. Roberts, J., "Structural Design of Flexible Sewer Pipes," *Journal of the Water Pollution Control Federation* 43(4) (Apr. 1972).

32. Ramseier, R. E., "Testing New Sewer Pipe Installations," *Journal of the Water Pollution Control Federation* 44(4) (Apr. 1972).

33. Environmental Protection Agency, "Guidelines for Sewer System Evaluation," preliminary draft (Apr. 1973).

34. Bailey, J. R., Benoit, R. J., Dodson, J. L., Robb, J. M., and Wallman, H., "A Study of Flow Reduction and Treatment of Waste Water From Households," General Dynamics, Electric Boat Division, EPA Contract No. 14-12-428 (Dec. 1969).

35. Howe, C. W., Russell, C. S., Young, R. A., and Vaughan, W. J., "Future Water Demands: The Impacts of Technological Change, Public Policies, and Changing Market Conditions on the Water Use Patterns of Selected Sectors of the United States Economy: 1970-1990," Resources for the Future, Inc., prepared for the National Water Commission (Mar. 1971).

36. Guarneri, C. A., Reed, R., and Renman, R. E., "Study of Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications," vols. 1 and 2, Contract NAS 9-12503, Grumman Aerospace Corp. (Dec. 1972).

37. Shumacher, E. A., "Study of Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications," 2 vols., Contract NAS 9-12504, Martin Marietta (Jan. 1973).

38. Murray, R. W., "Study of Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications," 2 vols., Contract NAS 9-12505, General Electric (May 1973).

39. American Water Works Association Committee of Water Use, *Journal of the American Water Works Association* (May 1973).

40. Caster, A. D., "Metropolitan Sewer District of Greater Cincinnati Program," *Journal of the Water Pollution Control Federation*, 43(3) (1971).

41. Boland, J. J., Hanke, S. H., and Church, R. L., "An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Sanitary Commission," Washington Suburban Sanitary Commission (1972).

42. Clausen, G. S., "Use of a Pricing Model for Efficient Water-Supply Allocation," Technical Report No. 1, Hydrology and Water Resources Office, University of Arizona (June 1970).

43. Headley, C., "The Relation of Family Income and Use of Water for Residential and Commercial Purposes in the San Francisco-Oakland Metropolitan Area," *Land Economics* 39 (Nov. 1963).

44. Fristoe, C. W., Goddard, F. O., and Keig, N. G., "Applied Criteria for Municipal Water Rate Structures," Department of Economics, College of Business Administration, University of Florida, OWRR Project C-1082.

45. American Water Works Association, *Water Rates Manual* (1960).

46. Ridge, R., "The Impact of Public Water Utility Pricing Policy on Industrial Demand and Reuse," General Electric Re-Entry and Environmental Systems Division, OWRR Contract 14-31-001-3697 (Nov. 1972).

47. American Chemical Society, *Cleaning Our Environment: The Chemical Basis for Action* (1969).

48. Environment Reporter, "Proposed Environmental Protection Agency Regulations for User Charge Systems and Industrial Cost Recovery," *The Bureau of National Affairs* 4(4) (May 25, 1973).

49. Ethridge, D. E., and Seagraves, J. A., "Two Methods of Studying the Effect of Municipal Sewer Surcharges on Food Processing Wastes," Economics Research Report No. 18, North Carolina State University (Dec. 1971).

50. Olson, Sherry A., "Some Conceptual Problems of Interpreting the Value of Water in Humid Regions," *Water Resources Research* (1st quarter 1966).

51. Wight, R. D., "A Unique Water System for an Integrated Steel Plant," *Industrial Process Design for Water Pollution Control*, vol. 3, American Institute Chemical Engineering (1970).

52. Gilkey and Beckman, *Water Requirements and Uses in Arizona Mineral Industry*, Bureau of Mines Information Circular 8162 (1963).

53. Berger, Herbert F., "Evaluating Water Reclamation Against Rising Costs of Water and Effluent Treatment," *Tappi* (Aug. 1966).

54. Russell, Cliffords S., *Industrial Water Use,* sec. 2, Report to the National Water Commission, Resources for the Future, Inc., Washington, D.C.

55. Gomez, Hector J., "Water Reuse at the Celulosa Y Derivades, S. A. Plants," *Proceedings, 23rd Industrial Waste Conference,* Purdue University (1968).

56. Eller, J., Ford, D. L., and Gloyna, E. F., "Water Reuse and Recycling in Industry," *Journal of American Water Works Association* (Mar. 1970).

57. National Canners Association, "Liquid Waste from Canning and Freezing Fruits and Vegetables," EPA Program No. 12060 EDK (Aug. 1971).

58. Aceto, N. C., Edwards, P. W., Eskew, R. K., Redfield, C. S., Hurley, R. R., and Hoersch, A., Jr., "Production of Leaf Meals from Vegetable Wastes in Rotary Alfalfa Driers," USDA Eastern Regional Laboratory, AIC-266 (1950).

59. Lund, D. B., "A Field Study on the Application of Individual Quick Blanching," *Proceedings of the Third National Symposium on Food Processing Waste,* National Environmental Research Center, EPA program element No. 1 B 2037 (Mar. 1972).

60. *Industrial Water Engineering,* (May-June 1973).

61. Letter from Abraham Groopman, Assistant Commissioner and Chief Engineer, to Dr. Robert Mason, Environmental Protection Agency, New York (June 14, 1973).

62. *Industrial Water Engineering,* (June-July 1972).

63. Rey, G., Lacy, W. J., and Cywin, A., "Industrial water reuse: future pollution solution," *Environmental Sciences and Technology* 5(9) (Sept. 1971).

64. "National Water-Use Study is Underway," *Chemical Engineering,* (Sept. 17, 1973).

65. Murray, C. R., "Water Use, Consumption, and Outlook in the U.S.," *Journal of American Water Works Association* (May 1973).

66. *The Nation's Water Resources,* U.S. Water Resources Council, Washington, D.C., (1968).

67. *Reverse Osmosis Concentration of Dilute Pulp and Paper Effluents,* U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12040 EEL 02/72, (Feb. 1972).

APPENDIX A

COST-EFFECTIVENESS EXAMPLES

The EPA cost-effectiveness guidelines determine which waste treatment management system or component part thereof will result in the minimum total resources costs (economic, social, environmental) necessary to meet Federal, State, or local wastewater requirements. Monetary (or economic) costs are evaluated in terms of equivalent annual cost using standard economic procedures, whereas nonmonetary costs (special and environmental) are accounted for descriptively to determine their significance and impact.

In a cost-effectiveness analysis, water is viewed as a resource that has both acquisition and disposal costs. The comparative total annual costs are evaluated over the useful life of alternative devices. The lowest total annual cost is generally considered cost-effective or practicable. Two opportunities exist for the installation of water-saving devices: the first is when a new water-saving device will replace an existing water device that is still operational; the second is for the new installation of a water-saving device or the necessary replacement of defective existing water devices.

The following examples evaluate the cost-effectiveness of a limited-flow shower head and a shallow-trap toilet. These water-saving devices are evaluated for new installations and replacement of existing operational water devices.

With the installation of a limited-flow shower head instead of a standard shower head for either new construction or the necessary replacement of a defective shower head, the total annual costs can be reduced from $34.38 to $22.67. When evaluating the replacement of a perfectly good standard shower head with a limited-flow shower head, assuming no salvage or resale value for the standard shower head, the amortized capital costs of the standard shower head will remain and must be considered in addition to the cost of the new limited-flow shower head for determining cost-effectiveness. Replacement of the standard shower head with a limited-flow shower head will still be practical and cost-effective, since the total annual costs will be reduced from $35.91 to $23.20.

The installation of a shallow-trap toilet for either new construction or the necessary replacement of a defective standard toilet will reduce the total annual cost from $48.83 to $38.88. If the present standard toilet is perfectly good and has no salvage value, there will be an existing amortized capital cost of $8.88 for the replaced functional standard toilet. The total annual cost of a shallow-trap toilet will then increase to $47.71, which is more costly than the $34.88 of the functional standard toilet. In this situation the existing replacement will not be cost-effective or practical at present prices. However, if water and treatment costs increase in the future, the replacement of the standard toilet can become cost-effective.

These two examples indicate it may be cost-effective to use flow-reduction devices for new construction or necessary replacement of existing water devices, but the replacement of functional devices may or may not be cost-effective.

Preceding page blank

Example No. 1

I. Assumptions

A. Water cost — $0.50/1,000 gal

B. Treatment cost — $0.50/1,000 gal

C. Energy cost* — $0.56/1,000 gal

*75 percent hot water at $0.75/1,000 gal + 25 percent cold water at $0.00/1,000 gal = $0.56/1,000 gal.

D. Water use

5 min/d
220 d/year
4 persons/shower

Hardware cost

	Limited-flow shower head (3 gal/min)	Standard shower head (5 gal/min)
Material cost	$10.00	$ 5.00
Installation cost	10.00	10.00
Total cost	20.00	15.00

E. Capital and installation cost: amortized at 8 percent interest and 20 years

II. Cost-effectiveness

A. New installations

	Limited-flow shower head	Standard shower head
Water used	13,200 gal/year	22,000 gal/year
Amortized capital cost	$ 2.04	$ 1.53
Annual maintenance	0.00	0.00
Water costs	6.60	11.00
Treatment cost	6.60	11.00
Energy cost	7.43	12.38
Total annual cost	16.67	35.91

B. Existing hardware

	Limited-flow shower head	Standard shower head
Water used	13,200 gal/year	22,000 gal/year
Amortized capital cost (new)	$ 2.04	$ 0.00
Amortized capital cost (old)	1.53	1.53
Annual maintenance	0.00	0.00
Water cost	6.60	11.00
Treatment cost	6.60	11.00
Energy cost	7.43	12.38
Total annual cost	24.20	35.91

Example No. 2

I. Assumptions

A. Water cost — $0.50/1,000 gal

B. Treatment cost — $0.50/1,000 gal

C. Water use — 5 flushes/day
365 d/year
4 persons/toilet

D. Toilet cost

	Shallow-trap toilet (3.5 gal/flush)	Standard toilet (5 gal/flush)
Material cost	$100.00	$40.00
Installation cost	30.00	30.00
Total cost	130.00	70.00

E. Capital and installation cost; amortized at 8 percent interest and 20 years

II. Cost-effectiveness

A. New installations

	Shallow-trap toilet	Standard toilet
Water used	25,500 gal/year	36,500 gal/year
Amortized capital cost	$ 12.77	$ 6.88
Annual maintenance	0.50	0.50
Water cost	12.78	18.25
Treatment cost	12.78	18.25
Total annual cost	38.83	43.88

B. Existing toilet

	Shallow-trap toilet	Standard toilet
Water used	25,550 gal/year	36,500 gal/year
Amortized capital cost (new)	$ 12.77	$ 0.00
Amortized capital cost (old)	6.88	6.88
Annual maintenance	0.50	0.50
Water cost	12.78	18.25
Treatment cost	12.78	18.25
Total annual cost	45.71	43.88

APPENDIX B

PRICING POLICIES

The price of water supplies is a factor in wastewater flow reduction since water "users can and will adjust their demands in view of the price of the water, the costs of their other inputs, and the value of their products."[18] This is true of domestic and industrial water demands. "In the case of residential demand, the implication is that, because of the small total expenditure on water, income effects of changes in water rates will be small, and that any substantial change in demand must come through the substitution effect."[19] The substitution effect is a consumer's willingness to substitute one material for another which will provide equal satisfaction. For example, a consumer may substitute travel by mass transit for travel by private automobile because of positive economic benefits. This substitution will occur when the satisfaction derived from the change is equal to the former state. Water cannot be substituted by other materials for cooking, drinking, bathing, or personal uses. However, substitute devices or requirements could be used to lower water consumption over a long period of time. Water-using fixtures and appliances within the home could be replaced by devices with lower water requirements.

When water meters are not used to establish water service charges, a flat rate is charged the users. A flat rate policy encourages wasteful use of water since an unmetered consumer will use water until the marginal value is nil and corresponds to a zero price.[18]

Metered water users can be charged a unit price for consumed water or a rate which varies with the type of use. If a consumer is charged for each unit of water used, the consumer is encouraged to eliminate wasteful water use.

When water rates are established by dividing the water system costs by the volume of water delivered,[20] "over investment in water supply facilities, need for promotional water to encourage full capacity use, and continuous pressure to expand the system"[21] are encouraged.

Declining block water rates are the most popular pricing methods in the United States. Ninety-four percent of the cities reporting in *Modern Water Rates* (1964-65) used this form of pricing.[22]

Declining block water rates or uniform water rates do not consider the strong seasonal pattern of water demands. Usually, urban water supply systems operate at levels well below their maximum capacity since the systems are designed for periods of high summer demand. The water facilities required to meet the last 12 percent of a community's summer demand almost doubles the capital costs.[22] If the public were aware of the extra cost of meeting the short-term summer demand, the water consumption probably would be reduced to avoid the additional capital costs.

The declining block water rates reward the large water user with lower average unit rates. Since the low water user is cheaper to supply per unit of water than is the large water

Preceding page blank

user,[22] the low water user, in essence, subsidizes the large water user by paying higher average costs. Uniform water rates do not reward the large water users with lower average rates or penalize them with higher rates.

Increasing block water rates charge higher unit prices in the higher consumption ranges and reward low water consumers with lower average unit prices. Summer differential water rates change more for water in the summer when the water demands are highest. An increasing block water rate has the effect of a summer differential policy since average unit prices will automatically be higher during periods of high consumption.

The determination of municipal water demands has been greatly influenced by past practices and customs and lack of sufficient data. Estimations of water demand are generally developed by multiplying population forecasts by an average daily per capita use and peak-to-average flow ratios. This procedure has caused substantially overdesigned or underdesigned water systems. Such water demand estimates do not make allowances for climate, economic levels, price, and other effects.

A study conducted by Johns Hopkins University attempted to define various elements of domestic water demand and characterize those elements which significantly influence water consumption.[19] The study examined 39 areas with homogenous physical and economic characteristics of the dwelling units. The Johns Hopkins study proposed basic equations for estimating the average daily water use (domestic use plus sprinkling), the maximum daily water use, and the peak hourly water use.

The report concluded that estimates of average annual and seasonal demands can be made using the basic equations, but selection of values for potential lawn-irrigation requirements are very difficult. Good estimations of water use were achieved when the characteristics of the study area were similar to those of the basic equation.

The Johns Hopkins study found water price elasticity to vary with consumer incomes, types of household use, and size of the city. Lawn sprinkling tends to be more price sensitive than any other water use. Water use in higher income areas and larger cities tends to be less price sensitive than in lower income areas and smaller towns. Generally, water demands, whether household, commercial, or industrial, tend to be price inelastic.

"The insensitivity of (water) use to price changes is . . . derived from the nature of consumption. A water-using consumer appliance or industrial process generally requires a specific water input to operate efficiently. The effective operation of the appliance or process is much more important to the user than the cost of water input. Furthermore, water costs tend to constitute only a minute portion of either the consumer's budget or the industrial firm's operating expense. However, in the long-run capital may be substituted for water inputs. Consumers may purchase recirculating air-conditioning units rather than maintain the nonconserving types. Commercial and industrial users may adopt less water-intensive processes or develop their own sources of supply as an effective substitute for municipal sources. Water users in more arid areas may abandon sprinkling. In essence, water users may substitute both water-conserving inputs and efficient management of water consumption over a wide range of uses."[23]

The organization of water supply agencies and sewer agencies in many municipalities does not allow the coordination of pricing policies to encourage wastewater flow reduction. In some instances the water supply agency may be independently promoting the sale of water. However, all municipalities applying for a Federal wastewater treatment grant must adopt a system of user charges to assure that each recipient of wastewater treatment services will pay his proportionate share of the operation and maintenance (including replacement) costs of the services.

U.S. GOVERNMENT PRINTING OFFICE 1971-482-412/28